OPTIMIZATION OF HYDRODYNAMICS BY INSTALLATION OF STATIC MIXER IN FLAT PANEL PHOTOBIOREACTOR

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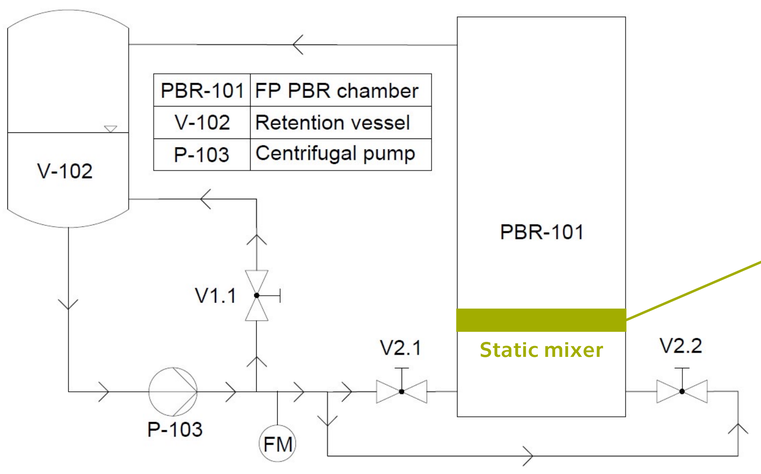
Introduction

Hydrodynamic conditions in pilot or industrial cultivation systems significantly affect the process of microalgae cultivation. It is necessary to ensure sufficient mixing and homogenous distribution of the flowing medium in the entire irradiated area of the photobioreactor (PBR). It is also important to prevent the formation of dead zones in which sedimentation or uneven retention of microalgal cells could occur. In order to intensify the mixing of the processed medium and homogenizes the flow in the entire cross-section of the flat panel PBR (FP PBR) chamber, the static mixer was designed.

Flat panel PBR design

Pilot FP PBR design characteristics	
Volume of one PBR panel	75 L
Amount of processed medium	100 L
Height of the panel	2000 mm
Width of the panel	700 mm
Depth of the panel	50 mm
Irradiated area	2.8 m^2



Static mixer

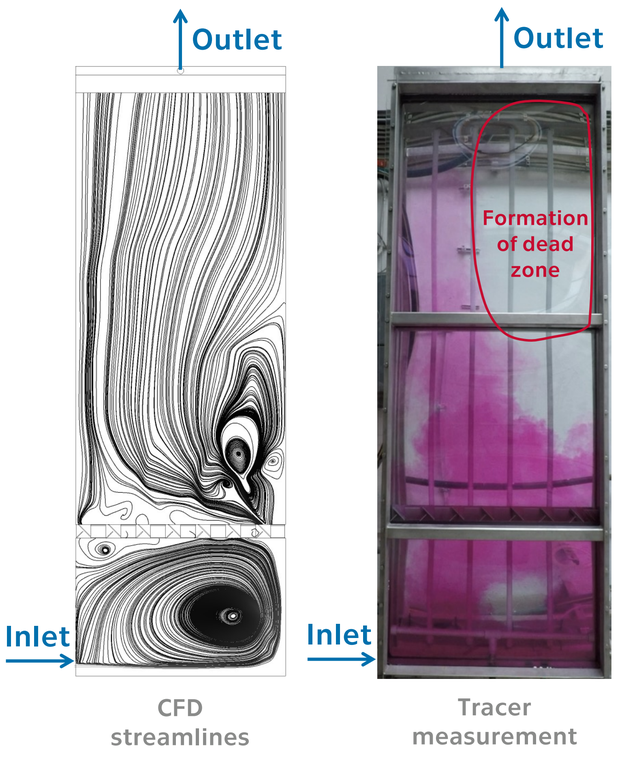
Installed static mixer in FP PBR chamber

The geometry and application of the static mixer is protected as a utility model (CZ 34865 U1, registered Feb 23, 2021)

CFD model validation

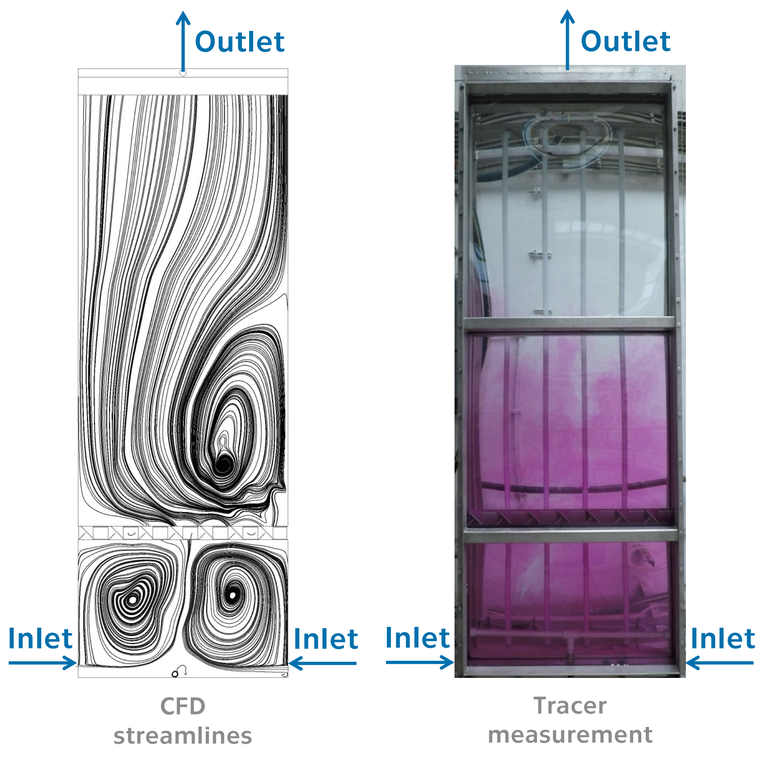
The pulse-input tracer method (phenolphthalein reacted with sodium hydroxide) was used for monitoring of flow. The tracer was applied to the retention vessel V-102. By setting the valves on the FP PBR chamber V2.1 and V2.2, the flow of the processed medium for two different configurations was monitored.

Single inlet configuration



CFD streamlines | Tracer measurement

Double inlet configuration

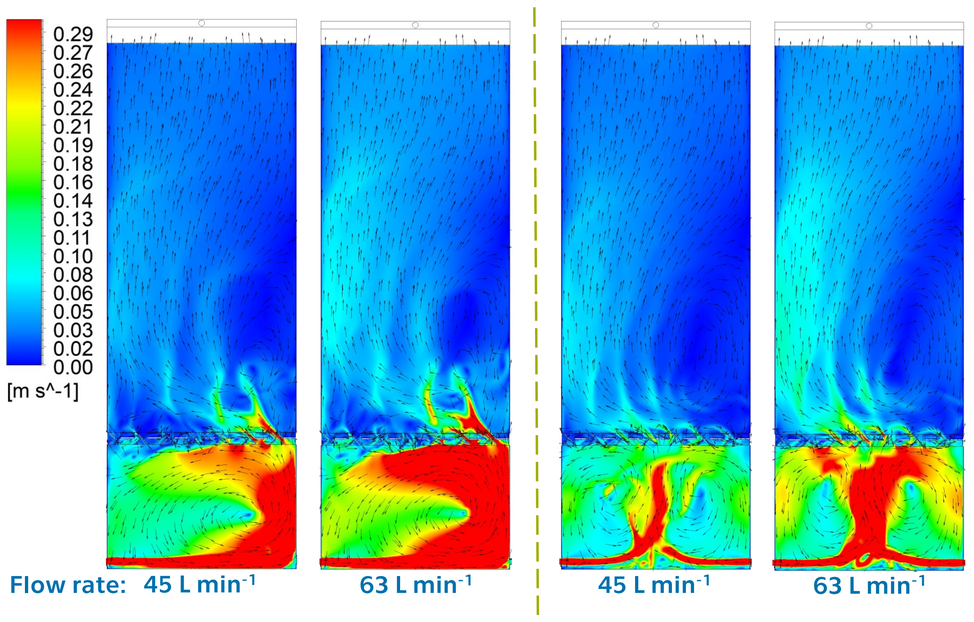


CFD streamlines | Tracer measurement

Based on the measurement, it can be determined that the measured and simulated streamlines were in a good agreement and the CFD model can be used to simulate various operating conditions in FP PBR with an installed static mixer.

Analysis of hydrodynamics

Velocity distribution in FP PBR chamber with static mixer



- Formation of circulation loop in the chamber below the static mixer
- Flow of culture medium only through the right side of the static mixer
- Formation of circulation loop in the upper part of the FP PBR chamber

- More uniform flow of medium to the center of the static mixer.
- Significantly more homogeneous flow distribution in the FP PBR chamber compared to the single inlet configuration.

Homogenization of flow in FP PBR chamber

Single inlet configuration

Inflow (L min^{-1})	HRT (s)	PBR configuration	Homogenization time (s)
45	97	Empty chamber	97
		Chamber with static mixer	113
63	68	Empty chamber	75
		Chamber with static mixer	78

Extension of homogenization time

Homogenization time is higher or equal to HRT

Double inlet configuration

Inflow (L min^{-1})	HRT (s)	PBR configuration	Homogenization time (s)
45	97	Empty chamber	78
		Chamber with static mixer	65
63	68	Empty chamber	64
		Chamber with static mixer	42

Shortening of homogenization time

Homogenization time is lower than HRT

Summary

- CFD model of FP PBR was calibrated based on tracer-injection experimental data
- Static mixer was developed to intensify the mixing of culture medium and homogenize the flow in the FP PBR chamber
- It is not possible to eliminate the circulation loop for single bottom configuration in FP chamber by installing static mixer
- Static mixer in double bottom configuration ensure more homogenous flow
- Formation of dead zone can be eliminated in double bottom configuration by installing the static mixer in FP PBR chamber
- Homogenization time was **extended** by 17 and 4 % in the single bottom configuration using a static mixer for flow rates of 45 and 63 L min^{-1}
- Homogenization time was **reduced** by 17 and 34 % in the double bottom configuration using a static mixer for flow rates of 45 and 63 L min^{-1}

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